Characteristics of Amorphous metal and Energy Efficient Amorphous metal Distribution Transformer

Hitachi Metals, Ltd.
Soft Magnetic Materials and Components Business Unit
http://hitachi-metals.co.jp
Outline

1. Introduction of Amorphous metal, Core and Transformer
2. Energy Loss and Efficiency in Transformer
3. World Wide Situation of AMDT
4. Recycle of Amorphous Core
5. Conclusions

*AMDT: (AMorphous metal Distribution Transformer)
1. Introduction of Amorphous metal, Core and Transformer
History of Amorphous metal

- **1973**: Developed amorphous metal, METGLAS® by Allied Signal
- **1976**: Developed amorphous metal for distribution transformer by Allied Signal
- **1982**: 1st amorphous distribution transformer (USA)
- **1989**: Mass production of amorphous metal (Metglas® 2605SA1) in Conway, SC, USA
- **1991**: Started to produce amorphous pole transformer in Japan
- **2003**: Acquisition of amorphous metal business unit by Hitachi Metals from Honeywell
- **2011**: Developed high permeability grade of amorphous metal (Metglas® 2605HB1M)
Rapid quenching cast technology
(Cooling rate: $10^6{^\circ}C/s$ and over)

Molten alloy is not crystallized to form solid alloy.

**Metglas® 2605SA1 & 2605HB1M**

Chemical composition: Fe, Si, B
Nominal thickness: 25 µm
Standard width: 142 mm, 170 mm, 213 mm
Uses of Amorphous Metal Alloys

- Wound Core
- METGLAS® Amorphous Ribbon
- Switched-mode Power Supply
- Choke Coil
- Current Sensor
- Wound Core
- Fe-based or Co-based
- METGLAS® Amorphous Ribbon
- Fe-based
- Fe-based
- Ni-based
- Fe-based or Co-based
- Distribution Transformer
- Transformer Segment is Highest Volume
- Powerlite® C-Core (Cut Core)
- High Efficiency Inverter (Wind or Solar Generator)
- Axial Gap Motor Stators (Future)
- Automobile
- Metal Joining
- Ribbon
- Brazing Foil
- Automobile
- Marker for Electronic Article Surveillance

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Geographical Locations of our Business Unit

- Conway, USA
- Yasugi, Japan
- Tottori, Japan
- Pan Yu, China
- Ayutthaya, Thailand
- Gurgaon, India
- USA

- Production (Material): 60,000 Ton/Yr
- Production (Components): 40,000 Ton/Yr
- Sales Offices
Features of Amorphous metal

Amorphous metal

- Random Atomic structure
  - Lack of crystalline anisotropy
    ⇒ Lower hysteresis loss
  - Higher resistivity
    ⇒ Lower eddy current loss

Crystalline metal (CRGO)

- Small thickness (0.025 mm)
  ⇒ Lower eddy current loss

1/3 of core loss compared to CRGO
Less heat from core

Infrared Photographs of (a) Metglas® Amorphous metal & (b) Grain Oriented Steel Distribution Transformer Core

*CRGO: Cold Rolled Grain Oriented Electrical Steel
Amorphous metal Transformer
Core Manufacturing

PRESPOOLING

CUTTING

STACKING

CORE LACING

CORE FORMING

ANNEALING

EDGE FINISHING
2. Energy Loss and Efficiency in Transformer
Amorphous metal Distribution Transformer (AMDT)

- Core
- Winding
- Bushing
- Oil Tank

Example: Oil-Immersed Single Phase DT

- Difference of parts in DT between AMDT and CRGO-DT is just a core.
- You can produce AMDT using traditional technique.
- Many people are worried that AM-core is very difficult to handle. But handling of AMC becomes easy after they have some experience.
- Hundreds of AMDT makers have mastered its production.
**Energy Loss in Transformer**

<table>
<thead>
<tr>
<th>Loss</th>
<th>Site</th>
<th>Major reason</th>
<th>Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>No load loss</td>
<td>Core</td>
<td>Hysteresis loss &amp; Eddy current loss</td>
<td>Constant at all times</td>
</tr>
<tr>
<td>Load loss</td>
<td>Coil</td>
<td>Electric resistance</td>
<td>Increase as square of load factor</td>
</tr>
</tbody>
</table>

**Example of loss and efficiency vs. load factor**

When LF is high: Load Loss (LL) is dominant in total loss

When LF is low: No Load Loss (NLL) is dominant in total loss

*Load factor = (Output)/(Rated capacity)*
# Load factor in Distribution Transformers (DTs)

Measured load factors of DTs in Vietnam

<table>
<thead>
<tr>
<th>Test site</th>
<th>Rated capacity (kVA)</th>
<th>Number of households</th>
<th>RMS load factor (%)</th>
<th>Max. load factor (%)</th>
<th>Min. load factor (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>400</td>
<td>300</td>
<td>16.6</td>
<td>35.9</td>
<td>5.9</td>
</tr>
<tr>
<td>2</td>
<td>400</td>
<td>320</td>
<td>35.2</td>
<td>107.7</td>
<td>4.5</td>
</tr>
<tr>
<td>3</td>
<td>1500</td>
<td>Hotel</td>
<td>28.4</td>
<td>57.2</td>
<td>5.3</td>
</tr>
<tr>
<td>4</td>
<td>560</td>
<td>factory</td>
<td>29.8</td>
<td>130.2</td>
<td>1.1</td>
</tr>
<tr>
<td>5</td>
<td>25</td>
<td>50</td>
<td>22.3</td>
<td>80.3</td>
<td>1.5</td>
</tr>
<tr>
<td>6</td>
<td>50</td>
<td>45</td>
<td>44.9</td>
<td>129.8</td>
<td>16.7</td>
</tr>
<tr>
<td>7</td>
<td>25</td>
<td>20</td>
<td>33.2</td>
<td>86.8</td>
<td>9.6</td>
</tr>
<tr>
<td>8</td>
<td>50</td>
<td>63</td>
<td>31.9</td>
<td>72</td>
<td>12.3</td>
</tr>
</tbody>
</table>

1. Residential area in suburbs of Hanoi, 2. Residential area near industrial park in suburbs of Hanoi, 3. Hotel in Ho Chi Minh City, 4. Factory in Dong Nai, 5-6, Residential area in Binh Duong The data measured from Oct to December 2011 as a part of project supported by NEDO.

RMS load factor: 20~40% should be considered to choose an adequate transformer
Transformer Loss Comparison

CRGO-DT
2nd Top Runner DT in Japan 1000kVA 50 Hz

AMDT
3. World Wide Situation of AMDT

<table>
<thead>
<tr>
<th>Country</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>230,000</td>
</tr>
<tr>
<td>USA</td>
<td>61,500</td>
</tr>
<tr>
<td>India</td>
<td>57,000</td>
</tr>
<tr>
<td>Japan</td>
<td>24,000</td>
</tr>
<tr>
<td>Mexico</td>
<td>17,000</td>
</tr>
<tr>
<td>South Korea</td>
<td>13,500</td>
</tr>
<tr>
<td>Taiwan</td>
<td>7,000</td>
</tr>
<tr>
<td>Canada</td>
<td>6,000</td>
</tr>
<tr>
<td>Philippines</td>
<td>4,000</td>
</tr>
<tr>
<td>EU</td>
<td>4,000</td>
</tr>
<tr>
<td>Brazil</td>
<td>1,800</td>
</tr>
<tr>
<td>Vietnam</td>
<td>1,800</td>
</tr>
<tr>
<td>Thailand</td>
<td>16</td>
</tr>
</tbody>
</table>

Unit: MVA

*Estimated by Hitachi Metals in Mar. 2016*
4. Recycle of Amorphous Core

Recycle process
Capacity: 50 MT/mo (April, 2013～)

Retrieve AM core from AMDT
Crush and Screen
Wash and Dry

Discard AMDT

Energy saving and Resource circulation

Recycle Flow of AMT (2013～)

AMDT
AMDT core
AM ribbon
Crushed AM core

50 MT/mo
April, 2013～
5. Conclusions

1. Amorphous alloy has been used in transformer more than 25 years

2. Manufacturing process of amorphous core and transformer are well-established under proven technologies.

3. Amorphous transformer is suitable for low RMS load factor area because of its low no load loss.

4. Amorphous transformers are installed in many countries.

5. Amorphous core recycling process has been established.
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